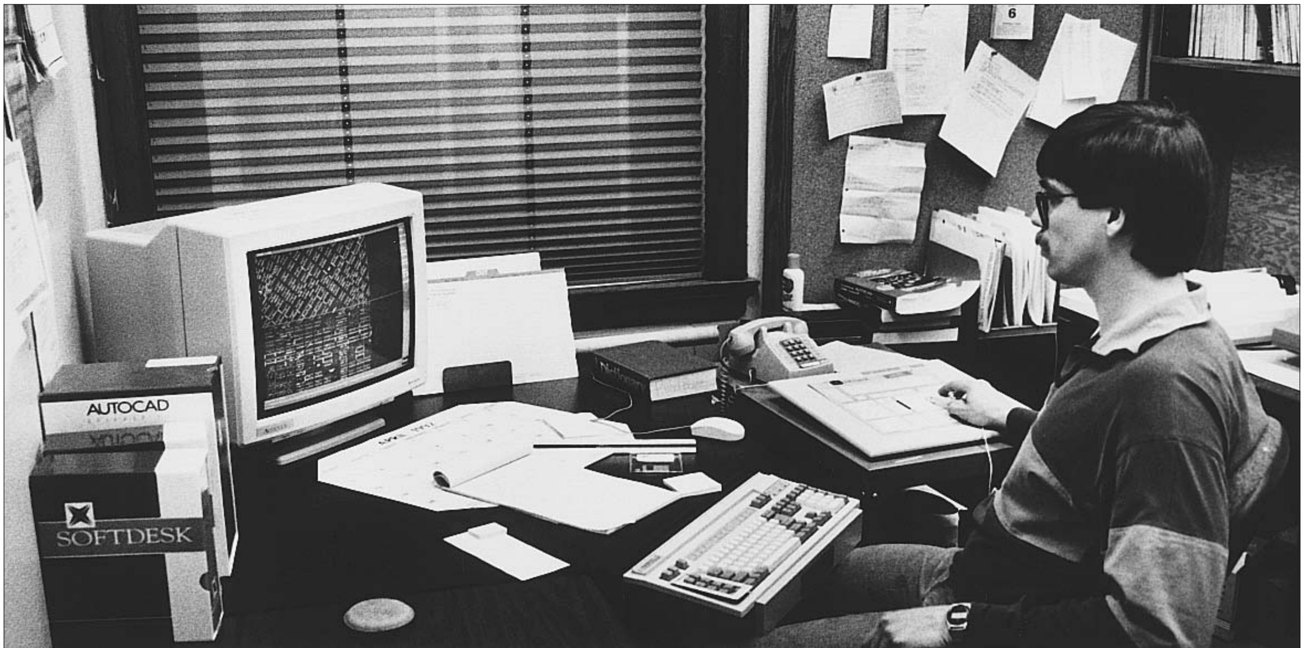
2 Planning For Bicycle Use



Planning for bicycle use involves learning about and responding to the expressed needs and desires of bicycling and non-bicycling residents.

Introduction: the planning process

Planning for bicycle use involves learning about and responding to the expressed needs and desires of residents by encouraging a healthy, environmentally-beneficial activity - bicycle riding. The potential benefits of bicycling to the community include reductions in transportation-related energy use, traffic congestion, improved air quality and public health.

The process of planning for bicycle use can be simple or complex depending on the needs and scale of the community. But whatever the scope, the following steps are suggested when planning for bicycle use.

(1.) Develop goals and objectives
(2.) Develop the planning framework
(3.) Analyze local conditions
(4.) Develop the problem statement
(5.) Generate solution ideas
(6.) Develop overall plan and select solutions
(7.) Implement projects
(8.) Evaluate results and revise

Step 1: Develop goals and objectives

The first step in planning for bicycle use is to develop the agency's goals and objectives for bicycling. These should be as specific and measurable as possible. Measurable, specific goals can be achieved more readily than vague, general goals.

Potential goals and objectives: The agency's overall goal may be to encourage increased use of the bicycle for utilitarian and recreational purposes. More specific sub-goals would include ones similar to those listed below, but more detailed objectives giving performance measures and approximate time frames.

Goal 1. Hazard elimination: Identify bicycling hazards on all streets in the community and work for their elimination.

Goal 2. Barrier elimination: Identify barriers to bicycling on all streets in the community and work for their elimination.

Goal 3. Behavior improvement: Identify the most important bicycling and motoring behavioral problems, in terms of bike safety, and work to correct them.

Goal 4. Institutional enhancements: Identify governmental policies (e.g. parking ordinances) which may be changed to enhance bicycle use and add appropriate "pro-bicycling" language.

Step 2: Develop planning framework

Comprehensive bicycle planning: Comprehensive bicycle planning encompasses four areas: engineering, education, enforcement and encouragement (Figure 2-1). In this manual, bicycle facility improvements are discussed as they relate to engineering. However, it is important that local agencies develop cooperative strategies in all four areas to implement a truly comprehensive program.

An incomplete program can result in unachieved goals. For example, if an engineering agency provides bicycle facilities, which attract new bicyclists, but the police fail to enforce basic bicycle traffic laws (e.g., using lights at night, riding with traffic, obeying stop signs), there may be more people riding unlawfully and, possibly, more bicycle crashes. Creating a bicycle advisory committee with representatives from all involved agencies, as well as members of the public, can be one very good way of developing such a comprehensive approach.

Integration with other plans: Planning for bicycle transportation also should be integrated into the overall transportation planning process. Often an improvement which enhances bicycle travel will also benefit other modes of travel. For example, wide outside lanes, added to a roadway to provide extra space for bicyclists, also benefit motorists by maintaining capacity in the curb lane.

Similarly, highway improvements, through appropriate planning and design, can enhance bicycle travel. For example, paved shoulders added to rural highways for the pupose of reducing motor vehicle accidents and maintenance can significantly improve those roads for bicycling.

Other plans, such as open space plans, outdoor recreation plans and land use plans , should address bicycle concerns as well. For example, uniform (and spread-out) land uses tend to increase distances between home, work and shopping, and make bicycling less feasible for many trips. Also, parking ordinances may include bicycle parking requirements. Virtually every plan can or may affect bicycle transportation in some manner and, therefore, should address bicycle concerns.

Step 3: Analyze local conditions

Successfully planning for bicycle transportation requires developing an understanding of current conditions and future needs. The two primary aspects to consider are user characteristics and environmental conditions.

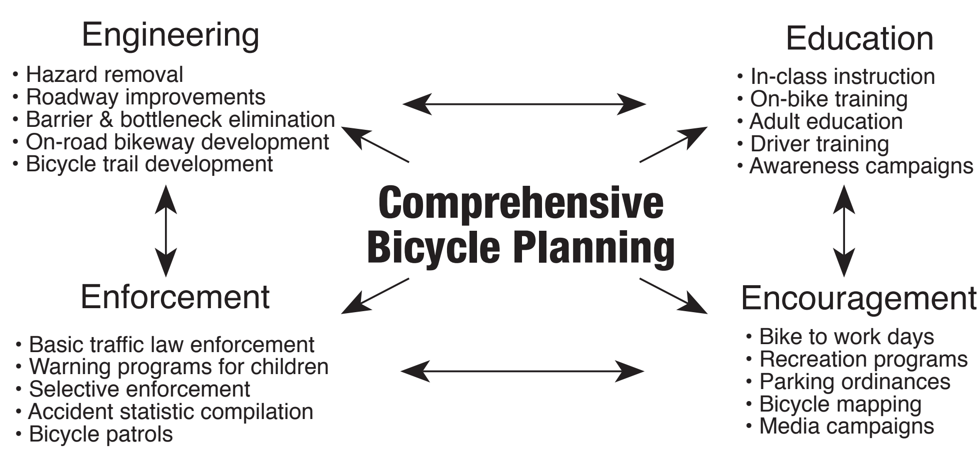


Figure 2-1: A model for comprehensive bicycle planning, encompassing the areas of engineering, education, enforcement and encouragement.

User characteristics:

Since satisfying the needs and desires of the users is the primary goal of bicycle planning, planners must learn as much as possible about the different groups who ride. Four main approaches are useful in gathering the necessary data: surveys, bicycle counts, behavioral observations and crash studies.

User surveys: User surveys give information on bicyclists' and non-bicyclists' attitudes, demographic characteristics and, to some extent, behavior. Demographic data of interest would include respondents' ages, sex, education, occupation and patterns of bicycle ownership.

Attitude data would include perceptions of cycling problems and interest in new opportunities for bicycle use. Behavior data would include factors like current levels of bicycle use, bicycling purposes, distances traveled and helmet and headlight use.

Since surveys must be carefully crafted if they are to be valid, it is important to get expert help. However, such assistance need not be expensive. For example, a local university professor may agree to give such a project to his or her students. Other opportunities for collecting affordable survey data may involve collaborating with similar agencies or public interest groups. Sharing costs will reduce the amount spent by each participant.

Three primary approaches for surveying bicyclists are telephone surveys, mail surveys and face-to-face surveys.

Telephone surveys: Telephone surveys involve calling a random sample of residents and asking a set of standardized questions. Phone surveys have the advantage of involving an operator in a central location, and they are relatively fast to conduct. This helps keep the costs down. However, phone interviewers get no visual clues by which to judge the answers, and getting a representative sample may be difficult depending on phone ownership patterns. Also, it is difficult to spend much time with the person being interviewed.

Mail surveys: Mail surveys involve distributing a printed survey form to a sample of residents and asking respondents to return the survey when completed. Mail surveys involve relatively low costs and provide a geographical distribution of residents. They are easy for respondents to complete and time is less of a factor. Standardization is a benefit, in terms of collecting statistics. However, it is difficult to ask open-ended questions which may need follow-up. In addition, response rates are generally low.

Face-to-face surveys: Face-to-face surveys involve personally asking respondents a set of questions. This approach is a good way to get answers to complex questions, since it allows the interviewer to ask probing follow-up questions. However, face-to-face surveys are time consuming, and uncontrolled factors, like the personal interaction with the interviewer and differences between the approaches of multiple interviewers, may affect the results.

Bicycle counts: Doing bicycle counts will help to determine baseline levels of current use. By identifying locations with high or low use, it is possible to determine where bicycle improvements are most likely to fill an existing need. At the same time, bicycle counts will not identify latent demand. Such information is best gathered through user surveys.

The first step is to identify key corridors for bicycle travel. Since there is likely to be little data on the subject, locations should be chosen based on intuition and a general feel for where bicyclists are likely to be found (e.g., near universities and schools, passing over key bridges, etc.). Within these corridors, one should identify locations where the most useful data may be gathered. For example, it may be important to know if bicyclists generally turn or go straight through a particular intersection. Next, it is important to decide on a time for counting. If recreational use is important, evening and weekend hours will be important. If utilitarian riding is important, commute times (for work and school) will be important.

Records of the bicycle counts should be kept in a safe place where they may be found in future years. The value of routine bicycle counts lies primarily in their ability to show change over time. Increases in bicycle use in a particular corridor from one year to the next may suggest that improvements implemented have met with users' approval, for example. Conversely, decreases in use may reflect a worsening bicycling environment.

For this reason, it is important to consider counts as part of an evaluation system. They should be performed on a routine basis, at least annually but preferably several times per year.

There are two primary counting techniques: manual counts and mechanical counts. The appropriate counting technique will depend on the available labor, equipment and the location of interest. Manual counts are best done at intersections, allowing counters to keep track of bicycle traffic on more than one street. Turn movements can also be recorded. Manual counts, however, are labor-intensive.

Mechanical counts are best done away from the influence of intersections. As a result, turning movements are not as easily recorded. However, labor is not a problem; this approach is quite useful for an agency that has the equipment. Specific tips on using each method follow.

Manual counts: Counters should be provided with standard forms with diagrams of the location that identify each movement with a unique number. Clipboards with mechanical counters may make counting easier. Otherwise, staff should tick off the number of bicyclists they see performing each movement. Volunteers can help agencies perform time-intensive manual counts.

Mechanical counts: The location for a mechanical count should be chosen carefully. The best situation is one that allows motor vehicle traffic to flow freely at speeds of 40 km/h (25 mph) or more without enhancing bicycle speed. Significant downhill grades allow bicyclists to approach motor vehicle speeds and, therefore, are not appropriate locations for mechanical counts. However, uphill grades work well.

Counters should be installed in pairs as in a speed study. Sensitivity should be set to detect bicycles. Any traffic moving significantly slower than the rest (e.g., 8 to 25 km/h (5 to 15 mph)) would likely be bicycles.

Behavioral observation: Observing bicyclist behavior and bicyclist-motorist interactions can help identify problems that otherwise would not be noticed. While crash data, for example, can highlight the most serious problems and user comments can report what people say or believe, behavioral observation can show what people actually do. In some cases, observing behavior can help determine priorities for educational programs and awareness campaigns. In others, it may expose quirks in the road network.

Typical behaviors: Common behaviors to consider when setting up observations include use of helmets and other safety equipment, general lane use and lane use when compared with destination at intersections, traffic law compliance and turning maneuvers.

Observation technique: The first step is to decide what behavior is important, using the list given above as a basis. Next, a simple checklist should be developed, presenting the options (e.g., wrong way vs. right way riding) in an easy-to-record fashion. Observers should be able to quickly check off which of the behaviors they see. Each observer should be trained prior to being sent into the field. Adequate training significantly improves the accuracy, reliability and consistency of the data. For more information on field work, see the previous section on bicycle counts.

Crash studies: Determining the major causes and locations of bicycle crashes is an important step in understanding a community's cycling problems.

Police crash reports: Police records are one of the best sources of information on a community's common crash types; however, the majority of bicycle crashes are not reported. Typically, only one serious car-bike crash in five is reported. Of the crashes that do not involve motor vehicles, only one in twenty are reported. As a result, police data can only give an indication of the problem. Even so, police records provide useful information (Stutts 1986).

One enlightening task is to categorize reported crashes according to the crash types developed for the National Highway Traffic Safety Administration. (See the Reference section at the end of this document for further information on crash types.)

Emergency room records: Another source of data on bicycle crashes is the hospital emergency room. In several North Carolina communities, hospitals have cooperated with crash researchers to compile data on the number of bicyclists seriously injured in crashes, their ages and sexes, and the general circumstances surrounding the crash. Collecting hospital data is a good way to determine the overall scope of the problem and learn some of the demographic factors of interest. However, hospital records are not generally a good source of detailed information on crash type. Police records are better for this purpose. To learn more about emergency room studies, see the reports listed in the Reference section.

Surveys: Contacting bicycle users is another way to get general information on local crash problems. Such information as the seriousness of injury, general type and location of crash (e.g., bike-bike, bike-car), bicyclist demographics, and time and day of crash may be gathered in this way. In order to accomplish several goals at once, a crash survey may be part of a more general bicycle user survey (see page 7).

Crash study implications: Information gathered through bicycle crash studies can help structure an agency's bicycle program in several ways. The two most important topics for analysis are as follows:

Bicycle crash locations: Through the three approaches listed above, it is possible to develop a map of bicycle crash locations. These locations should be investigated to identify any physical hazards which may contribute to accidents.

Behavioral factors: Bicyclist and motorist behavioral problems are the leading factors in most crashes. The studies may help isolate key errors, which may become the focus of education and public awareness programs.

Environmental conditions inventory:

In order to plan effectively for bicycle use, it is important to gain a detailed understanding of local environmental conditions. Local bicycle clubs may be a good source of information when inventorying local bicycle conditions.

Developing a map or set of maps of such conditions is a key ingredient in the bicycle planning process. The most important conditions fall into three main categories: barriers, hazards and bicycle traffic generators. Because locating these features can be a time-consuming and staff-intensive process, it is best to solicit information from the community. There are several ways to accomplish this goal.

Volunteer recruitment: A relatively small group of cycling volunteers can help conduct an environmental conditions inventory. By breaking the community into districts and giving a map of each one to a volunteer, one can make the task more manageable. Volunteers should use the lists of barriers and hazards on the following pages and should be briefed, as a group, on how to record their observations.

Public meetings: A series of public meetings can help staff identify key problems. By bringing a set of maps and encouraging attendees to note barriers or hazards of greatest concern, it is possible to collect a lot of data in a short period of time. Another approach is to attend regularly scheduled meetings of neighborhood associations. These may not bring in as much bicycling expertise as specially scheduled bike meetings, however.

Hang tags and postcards: In some communities, bicyclists are encouraged to note barriers or hazards on mailback postcards distributed through bicycle shops and other high-traffic locations. In other cases, hang tag surveys are hung from bike handlebars and cyclists are encouraged to send these back.

Surveys: See *User Surveys* (page 7) for information concerning how to conduct a survey.

Barrier identification: Since for most people bicycle trips tend to be shorter than motoring trips, physical features can act as barriers to bicycle travel. A 5 km (3 mi) detour to get around a railroad track, for example, may be an annoyance for those driving cars but may deter people from using bicycles for what would otherwise be a relatively short trip.

Identifying and eliminating such barriers can open up major portions of the road network for bicycle use. However, the cost of bicycle bridges and other such facilities should be weighed against the accompanying benefits. Identifying barriers is a simple process of noting such features on a map.

Common barriers: Common bicycle traffic barriers include limited access freeways and expressways; shopping centers; rivers, creeks, canals and lakes; dead-end streets and cul de sacs; linear parks; mountains and ravines; railroads and transit lines; and utility rights-of-way.

Hazard identification: Hazards on existing highways should be considered for their effects on bicycling. A hazard is a condition that has the potential to cause a bicycle crash. The vast majority of serious bicycle crashes are single-bike accidents in which the bicyclist either hits a stationary object or loses control due to surface problems or operator error.

The most common bicycling hazards fall into three primary categories: surface hazards, geometric hazards and operating hazards.

Surface hazards: Surface hazards involve problems with the roadway or pathway surface. The most important ones are listed below.

Unsafe drainage grates or utility covers: Parallel bar grates can catch wheels while grates and covers that are not flush with the roadway surface can damage a wheel or cause a fall.

Debris: Gravel, sand, glass and other debris tend to accumulate in certain areas (e.g., near the right edge of the roadway or at intersections). Such debris may cause loss of control. A bicyclist may experience a crash when swerving to avoid such conditions.

Rough shoulder or rumble strips: Rumble strips laid down on rural highway shoulders are intended to alert sleepy or unattentive drivers, but their roughness can cause bicyclists to lose control and crash. For this reason, bicyclists will often choose to ride in the travel lane to avoid them.

Rough pavement: Rough pavement can be a serious impediment to bicycling. Rough pavement includes potholes, ravelled edges and cracks (especially those going the direction of travel).

Excessive drop-offs at the gutter pan: Multiple overlays on curb and gutter sections can cause a pavement build-up and subsequent drop-off at the point where the pavement meets the gutter pan. This can result in a hazard to bicyclists.

Bridge expansion joints: Some bridge expansion joints are unlevel and can cause wheel damage when bicyclists pass over them.

Metal grate bridge decks: Some bridge deck designs can cause bicyclists difficulty in controlling their bicycles due to the unevenness of their surface.

Railroad crossings: On diagonal railroad crossings, the gap next to the rail can trap bicycle wheels, causing a fall. Rough crossings can cause wheel damage or falls.

Geometric hazards: Geometric hazards involve characteristics of the roadways other than the surface.

Narrow lanes or structures: Narrow lanes (i.e., less than 3.6 m to 4.2 m (12 ft to 14 ft) in width) make it difficult for motorists to pass bicyclists safely without shifting to adjacent lanes. On multi-lane roads or structures, motorists can shift into the adjacent same-direction lane, which is a relatively safe maneuver. However, on two-lane facilities, motorists must shift into the on-coming travel lane, a potentially dangerous situation. Often, they will try to stay in the lane and squeeze past the bicyclist instead.

High volume driveways: High volume commercial driveways, like those at fast food restaurants, can be more hazardous than less-used commercial driveways or residential driveways.

Sight obstructions: Sight restrictions like shrubs, fences or parked cars near intersections are significant factors in many car/bike crashes.

Traffic signals not bike-responsive: Many demand-actuated signal systems were designed and installed without attention to their effects on bicyclists. As a result, bicyclists may find it impossible to get a green light.

Operating hazards: Operating hazards involve specific characteristics of other traffic. The most important are listed below.

High speed traffic: High traffic speeds are often associated with a greater threat of fatal crashes. They are most hazardous when combined with high traffic volumes, high percentages of truck traffic, and narrow lane and shoulder widths.

High volume traffic: High volumes of motorized traffic serve as a deterrent to bicycling and may lead to more car-bike crashes. They also increase the stress levels on bicycle users.

High volumes of truck or RV traffic: On high-speed roads, trucks generate buffeting winds that can push bicyclists off to the right and then pull them back to the left. If the traffic lanes are narrow and there is no ridable shoulder, the presence of significant volumes of truck traffic can be a deterrent to safe and comfortable bicycle use. Also, on scenic narrow roads that are popular with tourists, RV side mirrors can strike bicyclists' heads.

Curbside auto parking: Short-term parking generally causes more problems than long-term parking because of the number of motorists entering and exiting the spaces and their cars. Diagonal parking is particularly troublesome for bicyclists, because motorists may often back well out into the travel lane in order to look for approaching traffic.

Bicycle Traffic Generators: Bicycle traffic tends to occur where residential areas are accessible to people's likely destinations. For most people, average bicycle trip lengths are under 8 km (5 mi), and, for this reason, isolated destinations will not attract much bicycle traffic. Areas near bicycle traffic generators should be reviewed to identify existing or potential bicycle travel.

Common bicycle traffic generators include major employment centers, downtown shopping areas, schools and universities, college residential areas, sports and recreation complexes and parks.

Step 4: Develop the problem statement

The information gathered in the previous step can be combined into a comprehensive statement of the problem. This statement includes two primary parts: a set of environmental conditions maps and accompanying descriptions of hazards, barriers, etc.; and a report outlining the non-physical situation. These documents give the basis upon which to judge potential problem solutions.

Environmental conditions maps: One map would show major barriers and hazardous sites. A larger map would show more detail on specific problems like non-responsive traffic signals and drainage grates. The accompanying description would discuss details not possible to show on the maps, including such features as site plans of particular intersections and photos of unique hazards.

Non-physical conditions report: This document would discuss findings of user surveys, behavioral observations, crash studies and bicycle counts.

Step 5: Generate solution ideas

Once a comprehensive list of problems has been assembled, it is possible to identify potential solutions by focusing on the problems one at a time. In many cases, the solutions are standard ideas; however, it is possible that analysis has identified some truly unique local situations.

In such cases, having a clear understanding of the standard options and a commitment to evaluating results will allow the designer to create a unique solution that both works and does not contribute to other problems.

The following is a list of potential solutions to some common problems.

Roadway improvements: Roadway improvements can solve many bicycling problems. The following ideas are explained in further detail in the subsequent chapters.

Replace unsafe drainage grates or utility covers: Parallel bar grates can be replaced with bicycle-safe models, and covers that are not flush with the surface of the roadway can be adjusted.

Sweep debris: A map may be developed showing the most serious locations. This map could help guide the maintenance department's work.

Remove shoulder rumble strips: Where not needed, rumble strips may be removed. Where they are needed, they may be located in such a manner as to present the minimal hazard for bicyclists.

Improve rough pavements: Bad stretches of pavement may be repaired or resurfaced.

Eliminate excessive drop-offs at the gutter pan: Excessive drop-offs can be eliminated by feathering out the asphalt at the point where the pavement edge meets the gutter pan during resurfacing. Consideration can also be given to milling the old pavement surface to prevent the build-up.

Repair bridge expansion joints: Rough or uneven bridge expansion joints should be inspected and repaired.

Improve diagonal railroad crossings: Diagonal railroad crossing problems may be solved by paving an apron which would allow bicyclists to cross at 90 degrees, by installing a flangeway filler next to the track, or by providing warning signs or markings.

Improve rough railroad crossings: Installing rubberized crossings can eliminate roughness and reduce long-term maintenance costs.

Remark or widen narrow lanes: In some cases, it is possible to widen outside lanes by remarking an existing street. In other cases, it may require reconstruction. Either way, wide lanes give bicyclists more room to maneuver in high-volume traffic.

Provide smoothly paved shoulders: Paving full-depth shoulders on high-speed rural-type roads gives cyclists more leeway and a less stressful ride.

Consolidate high-volume driveways: It may be possible to reduce the number of commercial driveways, to the benefit of passing motorists and bicyclists alike.

Remove sight obstructions: Sight restrictions should be removed through sight triangle ordinances and a routine program of sight obstruction elimination.

Replace non-responsive traffic signal detectors: Some existing signals can be adjusted to detect bicycles. In other cases, signal detector loops may be replaced with bicycle-responsive models.

Eliminate curbside auto parking: In some cases, it may be possible to eliminate on-street parking. In other cases, widening the outside travel lane will make it easier for bicyclists to ride farther away from the parked cars.

Special bicycle facilities: Special bicycle facilities may solve particular problems or provide opportunities for non-cyclists to try bicycling in a less-threatening environment. Examples include the following:

Bicycle routes: Identifying bicycle routes with signs may be a way to help bicyclists get to particular destinations, avoid high-stress corridors or ride on scenic but little-known roads.

Bike lanes: Bicycle lanes can delineate a portion of the available roadway for bicycle traffic. In so doing, they may reduce the sense of danger among inexperienced bicyclists.

Bicycle paths: Separate bicycle paths can help bicyclists get around a barrier or difficult traffic situation. They also may provide an enjoyable recreational experience.

Bicycle bridges: Bridges may be constructed that allow bicyclists to get over a river or other linear barrier.

Other options: Other physical improvements can provide support for bicycling as well.

Bicycle parking: Since every bicycle trip has a destination, bike parking facilities are a necessary adjunct to physical improvements. Parking should be provided at major traffic generators (e.g., shops and schools) and at mass transit stations to encourage intermodal travel.

Bicycle/transit connections: A number of communities have found that encouraging bicycling to transit stations results in increased transit use. Some, for example, have provided secure bicycle parking, while others have developed systems for allowing bicycles on trains or buses.

Non-physical improvements: Non-physical improvements should be an integral part of any overall plan for bicycling. The following are options that may be considered.

Bicycle maps: Bicycle maps provide an excellent way to let bicyclists know about route options and large-scale hazards. Often, safety and access information is included on the back.

Bicyclist training: Bicyclist education and training include many options, from developing community awareness through public service announcements to training adults and youngsters in on-road sessions.

Bicycle enforcement: Enforcement of traffic laws is basic to a comprehensive bicycle program. Some communities have implemented on-bike patrols, while others have focused on "selective enforcement" procedures. Selective enforcement involves looking closely at the community's bicycle accident picture and emphasizing those violations that lead directly to the most crashes.

Encouragement projects: Encouragement may include such things as "bike to work week," during which people are encouraged to ride their bicycles for utilitarian trips. It may include recreational rides for families, publicity campaigns or bicycle maps. Each of these options can encourage people to get on their bikes and ride.

Step 6: Select solutions and develop a plan

Developing an overall plan for bicycle transportation in a community is a process of matching the goals and objectives identified in Step 1 with the problems discovered in Step 3 and the solutions identified in Step 5, in light of the community's fiscal limitations.

The ideas in the plan should help solve the problems in order to achieve the goals in a timely fashion. Assembling cost information is an important part of developing the plan. When determining costs, it is best to consult local technical staff who will implement the projects. They also can point out cost-saving opportunities which otherwise might be missed.

The result will be an action plan which identifies those actions which can be easily accomplished and those which require major investment.

Step 7: Implement projects

Implementing the plan involves work on three related but distinct tasks: policy development, long-range planning and short-range planning.

Policy development: The first task may involve the agency in reviewing and altering ordinances and policies that affect routine functions; an example would be the adoption of a bicycle-safe drain grate standard. Policies in the areas of transportation, construction, zoning, parking and law enforcement are particularly important to review.

Long-range planning: The second task involves scheduling long-term investments that solve major problems or provide major opportunities; examples would be the development of a special barrier-breaking bicycle bridge or planning a lengthy bicycle path.

These projects may be identified in a bicycle plan, but many should be worked into the project priority lists in other related plans, for example, the community's transportation and recreation plans. Quite possibly, other unrelated projects planned for the near future, with some modifications, can solve bicycle problems as well.

Some projects (e.g., a trail network) may be implemented on a phased basis. In this way, it is not only possible to pay the costs over a period of years, but later phases may be altered based on the experience of the earlier ones. As an example, one community found that their 2.4 m (8 ft) wide bicycle paths were getting far more use than they had expected. Subsequent segments were paved to a 3.6 m (12 ft) width.

Other projects, such as a major bike bridge, must be accomplished in one step. However, it may be necessary for an agency to set aside funds until it can afford to build the entire project.

Short-range planning: The third task involves scheduling short-term, mostly small-scale improvements; examples of these might include fixing potholes on a particular street or installing a warning sign. Many of the items identified in the hazard inventory fall under the category of short-term planning. Typically, they may be completed in one or two years.

Often, these improvements may be accomplished with as little as a maintenance work order. In some cases, however, where many small projects are needed, setting up an annual "bicycle spot improvement" budget and a schedule for completion will be necessary.

Step 8: Evaluate results and revise

Evaluating the success of an agency's bicycle plan is an ongoing function very similar to the process of problem identification described in Step 3. It requires paying attention to changes in crash causes, bicycle use, and user satisfaction and making adjustments based on the results. Looking at bicycle crash reports, doing annual bicycle counts and observations, and user surveys allow an agency to determine whether the situation is improving and the goals of the program are being met.

Evaluation also requires watching for bicycle-related problems during an agency's routine maintenance procedures.

The remaining chapters of this manual offer detailed guidelines on how to accommodate bicyclists in transportation projects and recreational corridors.

3 Design Factors

An example of a bicycle-pedestrian bridge.

Planners and engineers have a wide range of options to enhance bicycle transportation. On the one hand, improvements can be simple, inexpensive and involve minimal design consideration. An example might be approving a change in bicycle-safe drainage grates used on local road projects. On the other hand, improvements can involve substantial allocations of funds, detailed design, and multi-year commitments to phased development. An example might be an extensive community-wide bicycle path network.

In order to adequately design for bicyclists, particularly when approaching large-scale projects, one must have a basic understanding of how bicycles operate. Most designers have an understanding of motor vehicle operation, but few have studied bicycle operation closely.

Bicycle and bicyclist characteristics

The physical space occupied by a bicycle is relatively modest. Generally, bicycles are between 600 mm and 750 mm (24 in and 30 in) wide from one end of the handlebars to the other. An adult tricycle or a bicycle trailer, on the other hand, is approximately 0.8 m to 1 m (32 in to 40 in) wide. The length of a bicycle is approximately 1.75 m (70 in); with a trailer, the length grows to 2.55 m to 2.75 m (102 in to 110 in). In determining the design of off-road facilities, the width is more critical than the length.

The height of an adult bicyclist on a bicycle is given as 2.3 m (88 in). This height takes into consideration the possibility that the bicyclist may be riding while standing up. Generally, adult riders are between 1.5 m and 1.8 m (60 in and 72 in) high while riding on the saddle.

While these dimensions give the physical space occupied by the bicycle and rider, the bicycle in motion requires additional space. One must also consider clearances and maneuvering allowances between the bicycle and static or moving obstructions. The following are typical clearances used in determining widths of bicycle facilities:

Typical clearances:

Maneuvering allowances:

To edge of pavement	0.3 m (1.0 ft)
Between bikes	0.8 m (2.5 ft)
Between bikes and peds	0.8 m (2.5 ft)

Lateral clearances:

To parked cars	0.6 m (2.0 ft)
To curb drop-off	0.6 m (2.0 ft)
To utility poles, trees, and hydrants	0.6 m (2.0 ft)
To soft shoulder	0.45 m (1.5 ft)
To sloped drop-off	0.3 m (1.0 ft)

Vertical clearance:

To overhead obstruction	0.6 m (2.0 ft)

Source: Bikeway Planning Criteria and Guidelines; ITTE, 1972

In determining design speeds, it is important to consider the average speeds of typical bicyclists, as well as other likely users. Studies have shown that the average speed of bicyclists is 16 km/h (10 mph). However, these studies may not account for the growing number of riders, whose speeds may easily exceed 32 km/h (20 mph).

An important consideration in setting bicycle path curve radii, particularly those on downgrades is the effect of speed on turning ability. When traveling at average speeds, a bicyclist cannot turn the handlebars more than a few degrees to either side without losing control.

Further, while bicyclists can lean into turns, few riders are comfortable leaning at angles above five to ten degrees. To do so puts the inexperienced rider at risk of either sliding out or hitting the inside pedal on the pavement. As a result of these factors, bike path curve radii should be designed in a conservative manner.

Another critical characteristic is stopping distance. Due to differences in brake type and quality and rider skill, stopping distances for bicyclists traveling at the same speed may vary dramatically. Some bicycles are equipped with coaster brakes attached to the rear wheel hub; others use caliper brakes that act on both wheels. Further differences are found between high quality caliper brakes with special brake pads and inexpensive ones equipped with relatively slick pads.

In addition, wet weather seriously reduces the effectiveness of most bike brakes. According to *Pedal Cycle Braking Performance: Effects of Brake Block and Rim Design* (Watt, TRRL 1980), some common bicycle brakes take over four times as far to stop in the rain as they do under dry conditions. Further, bikes equipped with aluminum alloy rims stop between twice and four times as quickly in the rain as similar bikes equipped with steel rims.

Complicating all these factors are the varying abilities of the riders themselves. Skilled bicyclists can stop far more quickly than can unskilled riders.

As a result, stopping sight distances are important factors to consider, particularly when designing curves and intersections on separate trail systems.

Design options

The rest of this manual describes specific design features and approaches for accommodating bicyclists both on- and off-road. The topics include:

- Roadway improvements
- Bicycle lanes
- Bicycle routes
- Bicycle paths
- Supplemental facilities
- Operation and maintenance